Determation of dV/dt values for domestic SiC Schottky diodes

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S V Sedykh, S B Rybalka, A Yu Drakin, A A Demidov, E A Kulchenkov
Bryansk State Technical University, Bryansk 241035, 50 let Oktyabrya 7, Russia

Abstract. In this study the dV/dt values for 4H-SiC commercial diodes have been determined experimentally. The experimental measuring tester for determination of dV/dt values of diodes at amplitude of impulse of reverse voltage V_A (V_A=100÷950 V) applied across the Schottky diode was constructed. It was determined that the dV/dt value almost linearly increase with increase of impulse of reverse voltage V_A (in interval of V_A=100÷900 V) applied across the 5DS402A9 diode for the first time. It is determined experimentally that at the maximal impulse of reverse voltage (900 V) applied across the silicon carbide commercial 5DS402A9 diode produced by domestic company the dV/dt value (148 V/ns) is comparable with others commercial diodes and therefore diode of this type can stably function in electric power circuit.

1. Introduction

It is known that the Schottky diodes on the base of silicon carbide (SiC) widely using in high-temperature power electronics [1]. Some type of SiC Schottky diodes have been designed earlier [2-6] and now is produced by russian company the ZAO «GRUPPA KREMNY EL» (Bryansk, Russia). The one of the important characteristics for silicon carbide Schottky diodes is value of dV/dt when the impulse of reverse voltage amplitude (V_A) applied across to diode. Devices with lower dV/dt capability are more susceptible to failure from large in-rush currents [7-9]. The number of some investigations with discussion about dV/dt effect is very limited and presented in general investigations of diodes by Infineon Technologies [7] and Wolfspeed (Cree Inc.) [8,9]. Study of the Infineon SiC diodes it is shown that dV/dt value equals 90-120 V/ns [7]. In C3D03060A type Wolfspeed diode value of dV/dt=295 V/ns (V_A=800 V) and for C4D10120A diode dV/dt=495 V/ns (V_A=1000 V) [8,9]. The dV/dt data for domestic silicon carbide diodes is unknown to present time and therefore the main goal of this work is to obtain experimentally its dV/dt values.

2. Materials and methods

The experimental measuring tester was constructed for testing of diodes on the dV/dt value. Scheme of measuring tester is presented in Fig. 1 The parameters for tester, in particular, allows carrying out measurement of dV/dt value in interval from 50 V/ns up to 200 V/ns at amplitude of impulse of reverse voltage applied across to diode V_A=300÷950 V. Analyses of oscillogram has been carried out with used Hantek DSO5102P oscillograph (bandwidth 100 MHz, refresh rate 1×10^9 s^{-1}). The reverse voltage front across to tested diode is formed switching on VT2 silicon carbide transistor. Small acceleration time has been provided by charge of input capacitance of the VT2 transistor with using of avalanche breakdown current of the VT1 transistor. Regulation process of dV/dt parameter has been realized by the R21 resistor. The tested Schottky diodes were connected to connectors marked as XS1 in Fig. 1. For testing was used the 5DS402A9 (Kremny) JBS type 4H-SiC Schottky diode (produced by domestic company ZAO «GRUPPA KREMNY EL») and C4D10120 (Wolfspeed) Schottky diode.

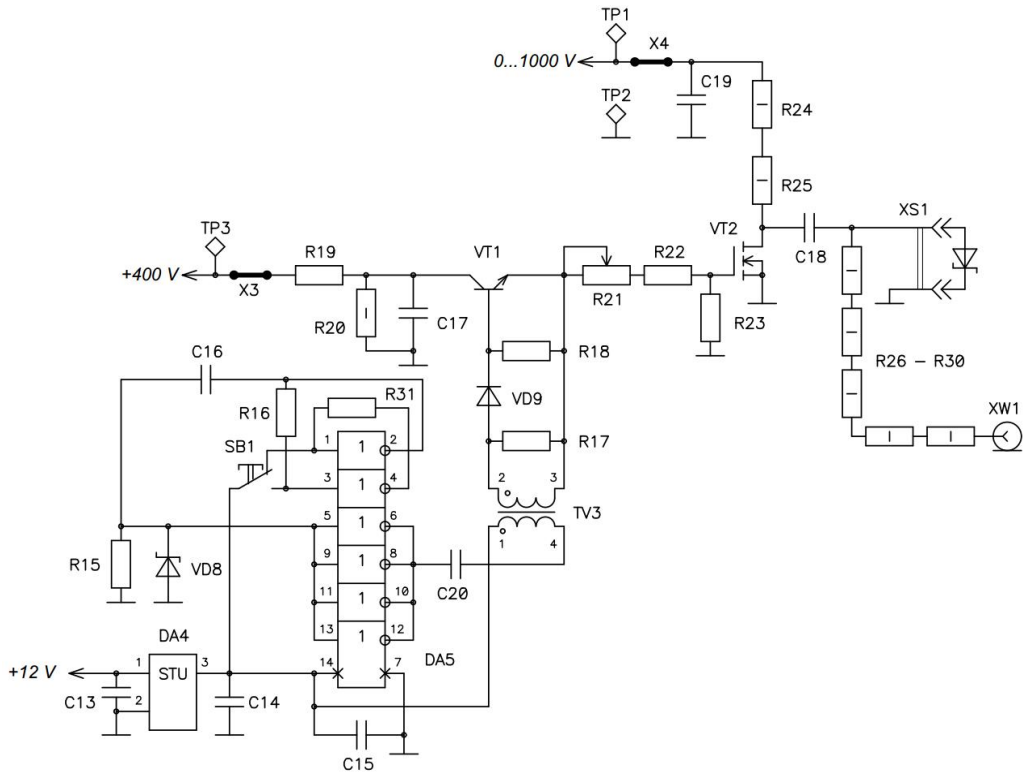

Figure 1. The scheme of the measuring tester circuit for determination of dV/dt value across a testing silicon carbide Schottky diode.

3. Results and discussion

In Fig. 2 are shown the testing results for 5DS402A9 (Kremny) silicon carbide Schottky diode and C4D10120 diode (Wolfspeed) at applied amplitude of impulse of reverse voltage across the diode 500 V. The value of dV/dt for diodes were obtained by slope of the linear part of oscilogram for voltage waveform, for example, as follows from Fig. 2 (curve *1*) for 5DS402A9 diode dV=168 V (380 V minus 212 V) and dt=2 ns (16 ns minus 14 ns), therefore the calculated value of dV/dt equals 84 V/ns. Similarly, for C4D10120 diode when the amplitude of impulse of reverse voltage applied across diode V_A=500 V the obtained value of dV/dt=132 V/ns as can be seen from Fig. 2 (curve *2*).

Then, as the amplitude of impulse of reverse voltage increase it lead to increase of dV/dt value. In Fig. 3 are shown testing results for 5DS402A9 silicon carbide Schottky diode (Kremny) and C4D10120 diode (Wolfspeed). The obtained value of dV/dt for 5DS402A9 diode (curve *1*) equals 148 V/ns at applied amplitude of impulse of reverse voltage across the diode 900 V. For C4D10120 diode (curve *2)* value of dV/dt at the same conditions equals 204 V/ns. In comparison with IDW20G120C5B (1200 V) commercial Schottky diode (Infineon) the obtained value for 5DS402A9 diode about two times more than the typically reported for dV/dt specification of 80 V/ns [10].

Further, with goal to establish the dependence between value of dV/dt and amplitude of impulse V_A applied across the SiC diode were carried out experiments by analogy with experiments described above. The obtained results then were generalized in Table 1.

As follows from Table 1, dV/dt values increase with increase of amplitude of impulse of reverse voltage V_A applied across the 5DS402A9 diode. Fig. 4 displays the dependence of the dV/dt value on the amplitude of impulse of reverse voltage V_A applied across the 5DS402A9 diode (obtained from Table 1 data). As can be seen from this figure the dV/dt dependence on V_A in this interval can be well approximate by the linear dependence.

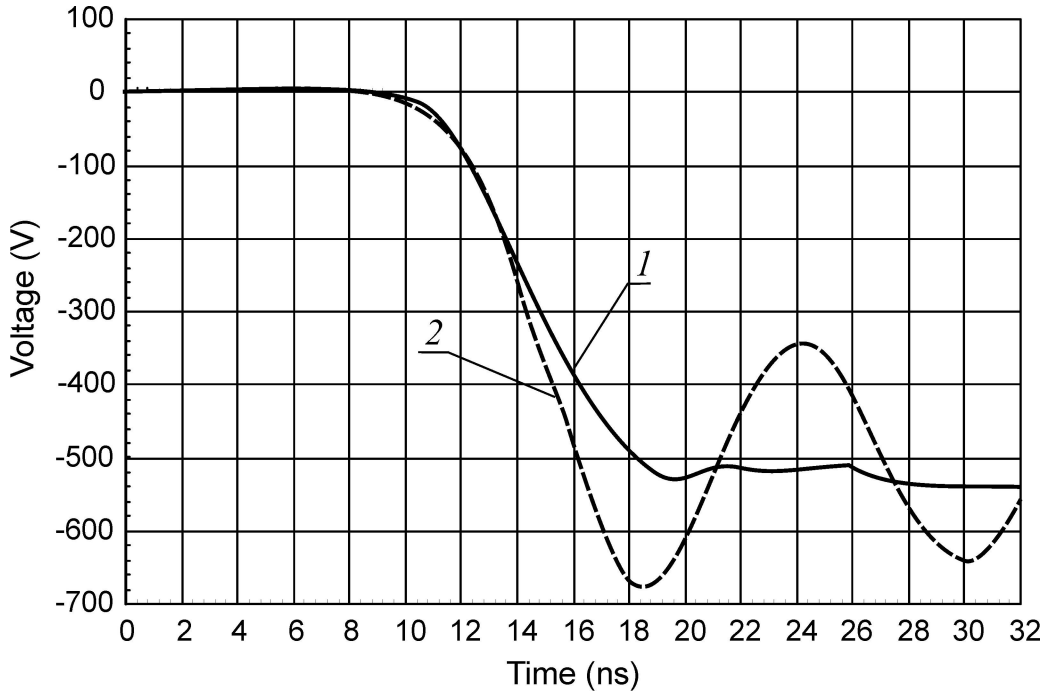

Figure 2. Reverse voltage waveform for diodes: *1* – 5DS402A9 (Kremny), *2* – C4D10120 (Wolfspeed) with impulse amplitude V_A=500 V.

Thus, to summarize the obtained results, it is established for the first time that dV/dt value almost linearly increase with increase of impulse of reverse voltage V_A applied across the 5DS402A9 diode in investigated interval of impulse voltage amplitude (from 100 up to 900 V).

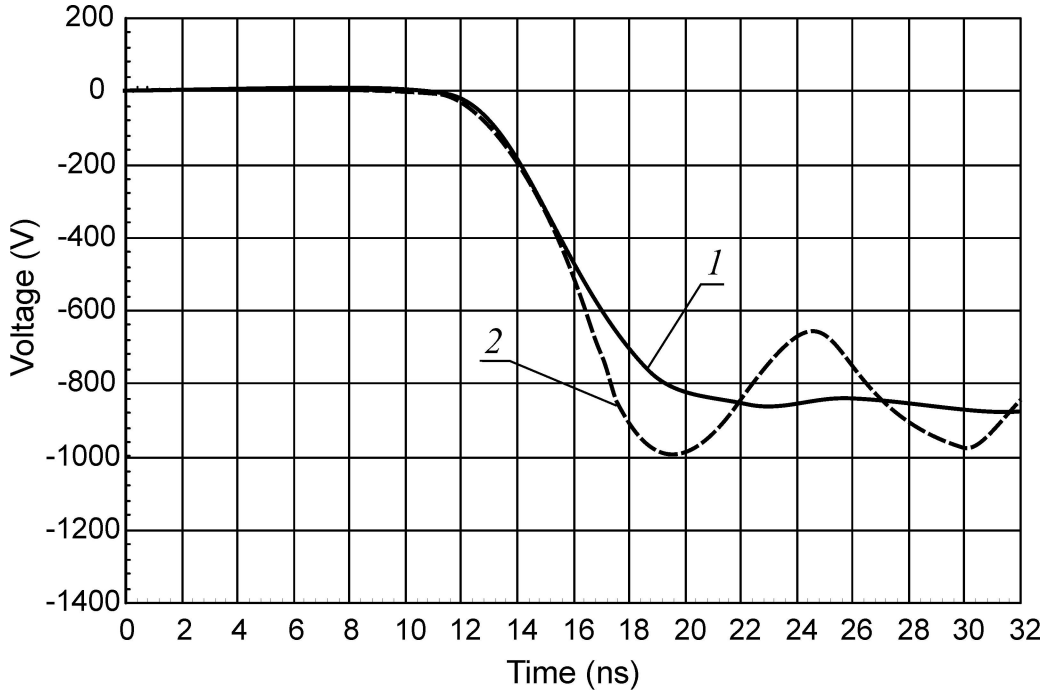

Figure 3. Reverse voltage waveform for diodes: *1* – 5DS402A9 (Kremny), *2* – C4D10120 (Wolfspeed) with impulse amplitude V_A=900 V.

Additionally, diodes were tested by 10^4 of cycles of impulse and was determined that studied diodes demonstrate the stable function without failure and breakdown.

Table 1. The value of dV/dt for diodes at various amplitude of impulse of reverse voltage applied across the 5DS402A9 diode.

V_A (V), amplitude of impulse of reverse voltage applied across the diode	dV/dt (V/ns)
100	19,6
200	36,4
300	49,2
400	64,8
500	84
600	94,4
700	107,2
800	125,6
900	148

Thus, on the basis of first experimental studying the obtained characteristics of dV/dt for russian 5DS402A9 commercial diode is comparable with other foreign SiC type commercial diodes.

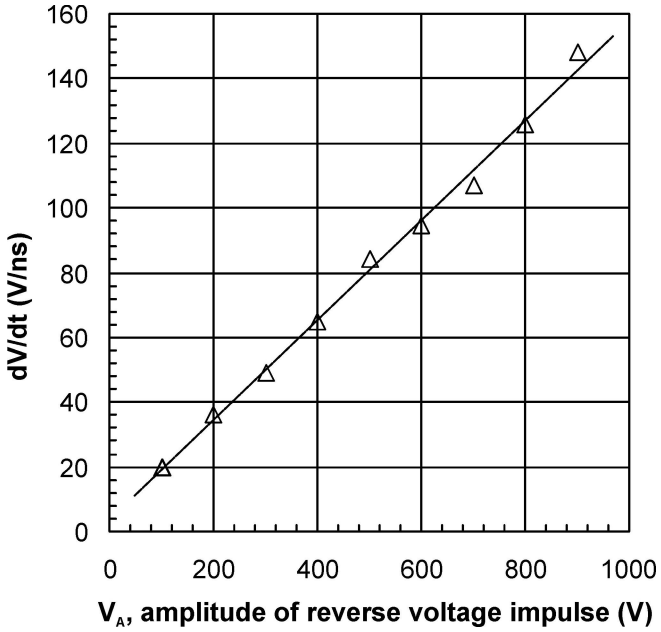

Figure 4. dV/dt dependence on amplitude of impulse of reverse voltage V_A applied across the 5DS402A9 type Schottky diode.

It should be noted that, for next modification of C4D10120A Wolfspeed diode (V_A=1000 V) dV/dt=495 V/ns that about two times more than for C4D10120 older type diode [8,9]. Because of this, recently it is shown that the silicon carbide Schottky diodes of new generation of the Wolfspeed firm can stably work without failures under high values of dV/dt up to 400 V/ns and at increase of dV/dt up to 650-800 V/ns [11,12]. However, there is possibility to increase the dV/dt value by using of diode's module as it was established earlier [6]. In particular, for module from diodes (4 diode of 5DS402A9 type) in case when the amplitude of impulse of reverse voltage across the 5DS402A9 diode's module

was increase up to 900 V the value of dV/dt=184 V/ns [6] (it is more than on ~28% than for one 5DS402A9 diode where dV/dt=148 V/ns). Therefore, it is important from practical viewpoint that using the power module produced from some ordinary diodes can considerably increase the dV/dt.

4. Conclusions.

The experimental measuring tester for determination of dV/dt characteristic of diodes at amplitude of impulse of reverse voltage V_A applied across the diode from 100 up to 950 V was constructed. The dV/dt values for domestic and foreign SiC commercial diode at amplitude of impulse of reverse voltage applied across the testing diodes from 100 V up to 900 V have been obtained.

It is determined that at the maximal impulse of reverse voltage applied across the diode (V_A=900 V) the dV/dt values for 5DS402A9 commercial diode produced by domestic company («Gruppa Kremny El», Bryansk, Russia) is 148 V/ns and for C4D10120 diode (Wolfspeed, Cree Inc.) the value of dV/dt at the same conditions equals 204 V/ns. Thus, obtained dV/dt values for 5DS402A9 diode are comparable with others commercial diodes (typical values are 80-120 V/ns).

For the first time it is determined that dV/dt value almost linearly increase with increase of impulse of reverse voltage V_A applied across the 5DS402A9 diode in voltage interval from 100 V up to 900 V.

It was noted that value of dV/dt can be increase by using of diode's module, i.e. for diode's module (consist of four diodes of the 5DS402A9 type) the dV/dt value increase up to 184 V/ns (V_A=900 V) that is more than on ~28% than for one 5DS402A9 diode. Moreover, the carried out dV/st analysis also shown that studied diodes demonstrate the stable work after 10^4 of cycles of impulse without failure.

Therefore, it is determined that domestic SiC commercial diode possess the dV/dt values that more then typical for these type devices (80-120 V/ns) and consequently can stably work without failures.

Acknowledgements

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